

Rapid Communication***Arctotheca calendula* (L.) Levyns (Asteraceae): an emerging invasive alien species in Iran**Samereh Tirgan¹, Alireza Naqinezhad¹ and Giuseppe Brundu^{2,*}¹Department of Plant Biology, Faculty of Basic Sciences, University of Mazandaran, P.O. Box 47416-95447, Babolsar, Iran²Department of Agricultural Sciences, University of Sassari, Viale Italia 39, 07100 Sassari, Italy

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OPEN ACCESS**Abstract**

The herb *Arctotheca calendula* (capeweed) is reported as a new record for Iran. A detailed description, a distribution map, colour photographs of an herbarium sample, and diagnostic features are provided to facilitate identification. The species was first observed in 2017 in the Miankaleh Biosphere Reserve, one of the thirteen UNESCO Biosphere Reserves in Iran. Since 2017, the *A. calendula* population has been thriving and locally expanding. As capeweed is generally described as an invasive species with negative impacts, having both high reproductive potential and highly mobile propagules, we suggest prioritizing an eradication intervention for this alien weed before it becomes too widespread.

Key words: Capeweed, Miankaleh Biosphere Reserve, rangeland weed, environmental alien

Introduction

Invasions of alien species are detrimental to the conservation of many different ecosystems and habitats (Vilà et al. 2011; Rai and Singh 2020; Pyšek et al. 2020; Morelli et al. 2021). However, coastal ecosystems (Carboni et al. 2010; Bazzichetto et al. 2018; Tordoni et al. 2021) and the protected areas within these ecosystems (Williams et al. 2019) are under threat in many parts of the world, and in many cases, severe degradation has been documented as a result of plant invasions (Campos et al. 2004; Medina 2006; Brundu et al. 2015).

Here, we report the first record of *Arctotheca calendula* (L.) Levyns, inside the Miankaleh Biosphere Reserve, which is one of thirteen Iranian Biosphere Reserves (UNESCO 2021), located along the south Caspian Sea coast in northern Iran.

Arctotheca calendula, belongs to the Arctotideae tribe, and the Arctotidinae subtribe of the Asteraceae family; this species is native to South Africa (McKenzie et al. 2006) and is extensively naturalized in Australia, likely because of accidental introductions as a contaminant of stock fodder and

packing straw (Wood 1994). It has also been introduced in many other regions of the globe, such as in the Mediterranean basin (e.g., Algeria, Italy, and Spain), in several European countries and on parts of the American continent (Verloove and Sánchez Gullón 2008; Brundu et al. 2015; Hamel et al. 2020). Capeweed is listed as a noxious weed in the USA and is described as a weed of cereals, oilseed rape and legume crops in Australia, where it causes severe yield losses. Moreover, *A. calendula* reduces the forage values of natural and artificial pastures, where it becomes dominant and negatively affects the value of livestock by reducing their weight (Brundu et al. 2015). Furthermore, ecological impacts have been described in California, where *A. calendula* is reported to efficiently compete with other species for water and space and to seriously threaten native plant communities by crowding out grasses, herbs, and small shrubs, particularly in coastal grasslands and riparian zones (Brundu et al. 2015).

Materials and methods

Field surveys and identification of the alien species

This alien plant was first detected in 2017 in the Miankaleh Biosphere Reserve in northern Iran, next to the South Caspian Sea coast. The invaded site was monitored by annual field surveys in the period 2017–2021, and specimens were collected during field surveys in May 2017, June 2019 and June 2021. The Biosphere Reserve covers a total area of approximately 688 km²; it has been an important conservation area since 1970 and was declared a UNESCO Biosphere Reserve in 1976 (Ramsar Convention Bureau 2002). It embraces a variety of types of protected South Caspian Sea coastal habitats, such as coastal sand dunes, shrublands, and salt marshes and all the sequences of plant communities (Shokri et al. 2004; Ejtehadi et al. 2005; Asri et al. 2007). Importantly, *A. calendula* has never been recorded before in floristic and ecological studies carried out in this Reserve (see Ejtehadi et al. 2003, 2005; Shokri et al. 2004; Asri et al. 2007; Sharifnia et al. 2007; Tamartash et al. 2009; Saeidi Mehrvarz et al. 2015; Mahdavi et al. 2017).

The morphological diagnostic traits of this alien species, although it is often reported as a species complex (McKenzie and Bergh 2018), were observed both in the field and on plant material collected during the field surveys. The specimens were identified according to Herman and Retief (1997), crosschecking other sources, such as Flora Iranica (Rechinger 1972–1989), Flora of Iran (Assadi et al. 2008–2018), Flora Europaea (Webb 1976), and McKenzie et al. (2005). All features of the specimens were thoroughly examined by stereomicroscopy, and the samples were deposited at the University of Mazandaran Herbarium (HUMZ). The virtual online herbaria of Vienna (W), Kew (K), and Geneva (G) were also carefully surveyed.

The Euro-Med checklist (Euro+Med 2006), EPPO Global Database (<https://gd.eppo.int/taxon/AROCA/distribution>), the Global Register of

Introduced and Invasive Species – GRIIS (Keshavarzi et al. 2020), and the Global Biodiversity Information Facility (GBIF.org 2021) were checked to verify the current known distribution of *A. calendula* and the absence of previous records for Iran.

Results

Taxonomy and nomenclature

***Arctotheca calendula* (L.) Levyns, Journ. South Afr. Bot. 8: 284 (1942)
(Asteraceae)**

(Figures 1, 2A–L).

Main synonyms: *Arctotis calendula* L., Sp. Pl. 2: 922 (1753); *Arctotis tristis* L., Sp. Pl. 2: 922 (1753); *Arctotis superba* L., Cent. Pl. II. 32 (1756); *Arctotis calendulacea* L., Syst. Nat., ed. 12. 2: 578 (1767); *Arctotis sulphurea* Gaertn., Fruct. Sem. Pl. 2(3): 439 (1791); *Arctotis speciosa* Salisb., Prodr. Stirp. Chap. Allerton 209 (1796); *Arctotis hypochondriaca* Willd., Sp. Pl., ed. 4 [Willdenow] 3(3): 2348 (1803); *Cryptostemma calendulaceum* (L.) R.Br., Hort. Kew., ed. 2 [W.T.Aiton] 5: 141 (1813); *Cryptostemma hypochondriacum* R.Br., Hort. Kew., ed. 2 [W.T.Aiton] 5: 141 (1813); *Cryptostemma runcinatum* R.Br., Hort. Kew., ed. 2 [W.T.Aiton] 5: 141 (1813); *Cynotis hypochondriaca* Hoffmanns, Verz. Pfl.-Kult. Nachtr. 2: 98 (1826); *Alloiozonium arctotideum* Kunze, Linnaea 17(5): 572 (1844); *Cryptostemma calendula* (L.) Druce, Bot. Exch. Club Brit. Isles Rep. 3(5): 416 (1914); *Arctotheca calendulacea* (R.Br.) K. Lewin, Repert. Spec. Nov. Regni Veg. Beih. 11: 49 (1922).

Specimens examined

IRAN, Mazandaran Province: Behshahr, Miankaleh Biosphere Reserve, southern coast of the Caspian Sea (Figure 3A), on coastal fixed sand dunes disturbed by grazing, trampling, soil compaction from heavy transport vehicles, 14 m b.s.l., 36°52'12.30"N; 53°33'01.70"E, 04 May 2017, A. Naqinezhad and S. Tirgan 9001 (HUMZ!).

Description

Annual herb, up to 26–34 cm high. Stems usually decumbent, ribbed and soft, with setose hair that is apparently magenta below flowers. Basal leaves rosette, 24–27 cm long and 5–5.5 cm width, stem leaves alternate. Leaves lyrate-pinnatisect, irregularly deeply lobed and sharply toothed, slightly hairy above and whitish, tomentose underside. Inflorescence capitula or head of solitary flowers, 2–2.5 cm in diameter on hairy stalks approximately 10–21 cm long. The receptacle flat and without chaff, Phyllaries (bracts of the involucre, the supporting structure below the flower head) strongly in 5 rows, green in colour with membranous margins and backwards curving tips. The ray flowers 15–20 and sterile. Ray corollas 20 × 2.5–30 × 4 mm long, pale yellow on upper half, mostly darker yellow below, purple or greenish at the base. Disk flowers greenish-black, numerous. Cypsela approximately 2.5 mm long by 1.7 mm wide, the dark brown cypselae egg-shaped and flat, with the narrow end at the bottom and densely lanate.



Figure 1. *Arctotheca calendula* exsiccatum collected in the Miankaleh Biosphere Reserve in 2017 and stored at HUMZ.

The faces rounded, the back arched, with 3 ribs; the outer coat, or testa, granular and rugose. The persistent pappus with 7–8, 9 chaffy scales.

Capeweed is very similar to *Gazania linearis* Druce and *Gazania rigens* Moench, which are very popular ornamental plants, and similar to *Arctotheca populifolia* (Bergius) Norl. (beach daisy) and *Arctotis stoechadifolia* P.J. Bergiu (white arctotis). These species can be distinguished by the careful examination of key diagnostic morphological traits of capeweed, such as elongated deeply lobed (i.e., lyrate-pinnatisect) leaves with green upper surfaces and whitish hairy undersides and relatively large flower heads.

Invaded sites in Iran

Arctotheca calendula thrives in open grasslands with shrubland patches in rangelands located along the South Caspian Sea coast (Figure 3A–D). Four

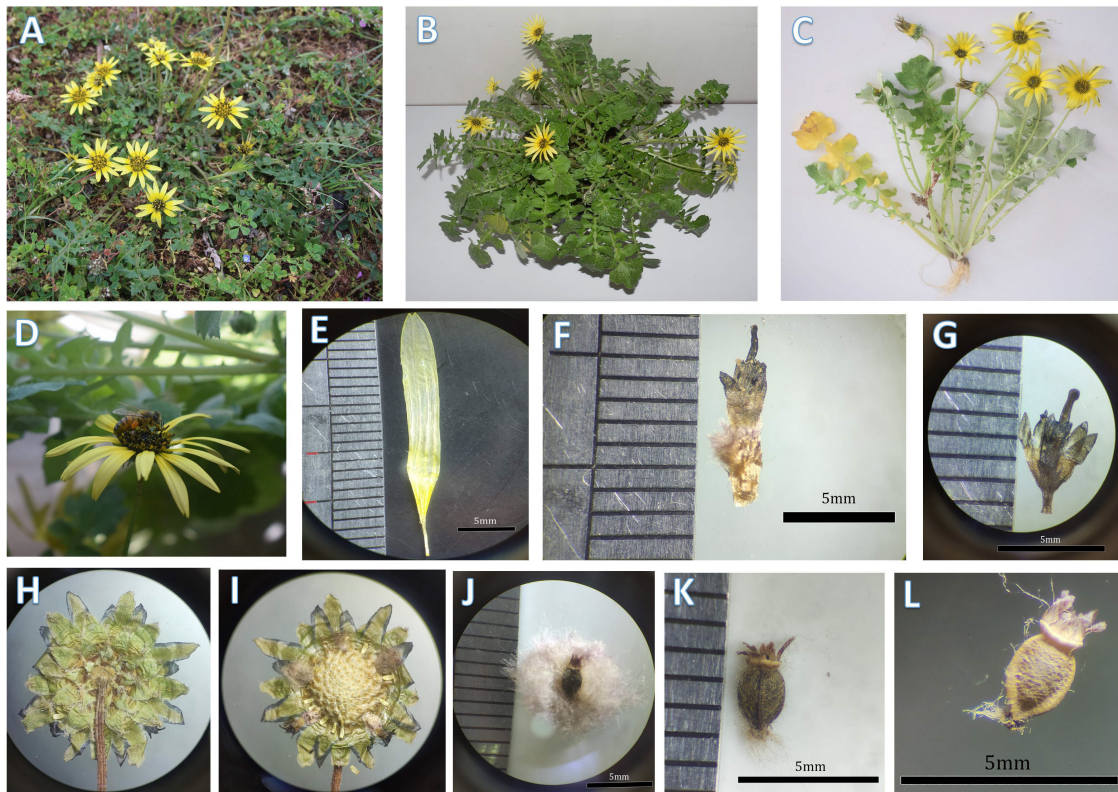


Figure 2. *Arctotheca calendula* showing its habit in the field (A) and cultivated (B and C), with a pollinator (bee) on flower-head (D), ray corolla (E), disc flower and corolla, respectively (F and G), Phyllaries (H and I), densely lanate cypselae (woolly indumentum teased back to expose the fruit) (J), cypselae backwards and frontwards, respectively (K and L). Photos by Alireza Naqinezhad (A) and by Samereh Tirgan (B–L).

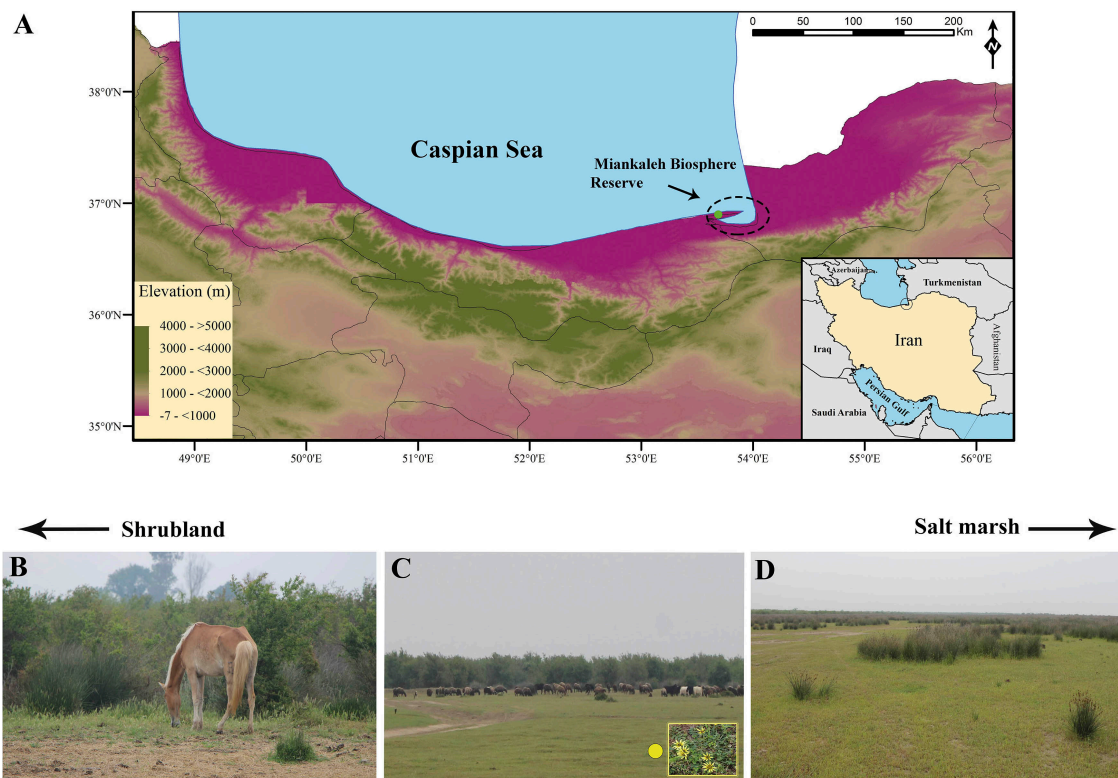


Figure 3. Map (A) shows the location (green dot) within the Miankaleh Biosphere Reserve, where *Arctotheca calendula* was recorded in 2017. The three photos (B, C, D) show a grazing horse in the shrubland (B), the invaded site (C) – a disturbed area of fixed dunes with grazing buffalos – with a yellow dot pointing at the exact location of the first record, and (D) the close salt marsh area (D). Site C is located between sites B and D. Photos by Alireza Naqinezhad and Samereh Tirgan.

rangeland sites were found to be invaded by this species within a radius of 8 km. At each site, small patches ranging in size from 1 to 4 m² were observed. However, other sites in the Miankaleh Reserve might have been invaded by this alien species and were not detected during our surveys. The invaded area is characterized by stabilized sandy soils covered by *Punica granatum* shrublands (see Saeidi Mehrvarz et al. 2015). From a phytosociological perspective, these habitats include several plant associations, such as *Junco littoralis* – *Punicetum granati*, *Junco littoralis* – *Rubetum sancti*, *Mespilo germanicae* – *Punicetum granati*, *Punicetum granati*, *Rhamno pallasii* – *Punicetum granati*, and *Rubo sancti* – *Punicetum granati* (Asri et al. 2007). Despite a dominance of shrubland patches over the area, these communities also include large grasslands rich in light-adapted and ruderal plant species such as *Erigeron bonariensis* L., *Pennisetum glaucum* (L.) R.Br., *Trifolium* sp.pl., *Cynodon dactylon* (L.) Pers., *Anagallis arvensis* L. subsp. *arvensis* var. *arvensis*, *Veronica* sp.pl., *Erodium cicutarium* (L.) L'Hér., *Capsella bursa-pastoris* (L.) Medik., *Sisymbrium officinale* (L.) Scop., *Juncus acutus* L., *Centaurea iberica* Trevir. ex Spreng., and *Plantago* sp.pl.

Discussion

Despite their great importance from the viewpoint of nature conservation and plant diversity (e.g., Kiani et al. 2017), coastal and sand dune ecosystems both in Iran and in many other parts of the globe are jeopardized by different types of disturbance (e.g., grazing, trampling, recreational activities, urbanization and construction of roads and paths, and invasive alien plants, e.g., Tordoni et al. 2021). Importantly, both in its native range, in South Africa, and in the invaded range, capeweed prefers sandy, well-drained soil, sand dunes, stream banks and rocky outcrops (Wood 1994; Brossard et al. 2000; Campos et al. 2004; Talavera and Talavera 2015; Hamel et al. 2020). Similarly, the invaded area in Iran is characterized by stabilized sandy soils.

The population of *A. calendula* in the Miankaleh Biosphere Reserve of northern Iran is currently limited to small areas in the Reserve. However, capeweed is known to have both high reproductive potential and highly mobile propagules (Lehtonen 2009); additionally, it can develop resistance to plant protection products (Khalil et al. 2021) so that in the absence of rapid control interventions and, possibly, eradication, it will establish and spread further, with negative impacts on natural habitats in this important coastal Biosphere Reserve. Other well-known invasive traits of *A. calendula* are effective wind and water dispersal mechanisms (Dunbabin and Cocks 1999), the ability to develop genotypes featuring variable seed dormancy and thus fitted to different environmental conditions, and the production of a high number of seeds in a short lifespan. As a result, this invasive species can thrive in a wide range of ecological niches (de la Riva et al. 2019; Saldaña-López et al. 2021).

The pathway of introduction of *Arctotheca calendula* in the Miankaleh Biosphere Reserve is unknown. However, the Miankaleh Biosphere Reserve represents a unique habitat for migratory birds. Birds might have acted as vectors for introduction, and they could act as vectors for secondary spread (Viana et al. 2013). Furthermore, contaminated forage seeds and hay are relevant pathways for the potential introduction of alien plants in rangelands (e.g., Cossu et al. 2020). Moreover, livestock, in particular buffalos and sheep, have been raised extensively in the Miankaleh Biosphere Reserve, resulting in modification of the flora and vegetation, which may promote the establishment of new alien and invasive species (cf. Belsky and Gelbard 2000). Furthermore, once established, the local dispersal of *Arctotheca calendula* can be promoted by wind, livestock and native bird species movements (Wang et al. 2018; Liu et al. 2021).

As mentioned above, *A. calendula* can easily become dominant in new places; it easily covers very large areas and engages in using water resources in competition with other native species (Brundu et al. 2015). Therefore, we believe that the occurrence of *A. calendula* in the northern part of Iran should be controlled promptly and prioritized for eradication intervention.

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Author’s contribution

ST: has made substantial contributions to research conceptualization, sample design and methodology, investigation and data collection, data analysis and interpretation, and writing the original draft; AN: has made substantial contributions to research conceptualization, data analysis and interpretation, writing, review and editing; GB: has made substantial contributions to data analysis and interpretation, writing, review and editing.

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